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Investigation of Thermal Conductivity of water with Al_2O_3 Nanoparticles

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ABSTRACT

In Thermal systems, Heat transfer fluids play a significant role. But conventional temperature transfer fluids have poor temperature transfer features. Many researches are created in order to improve the thermal properties of regular fluids. The improvement of thermal conductivity of regular fluids by micro-sized solid particles will not result in a valuable change. Therefore, Nanoparticles are put into it to create sizeable heat transfer liquids. Metal oxide nanoparticles i.e. Al_2O_3 is confusing with water and thermal conductivity of the blend is certainly investigated at different temperature ranges. It is discovered that the thermal conductivity boosts by 5%. The evaluation summarizes that the effective thermal conductivity of the Nano fluids boosts beyond 55°C.

Keywords: Heat transfer, Thermal conductivity, Al_2O_3, Metal oxide.

1. INTRODUCTION

Most significant industries including microelectronics, production, metrology, etc have already been applied in the cooling procedure by way of fluids. With raising thermal loads that want developments in cooling the brand new higher power output devices with quicker speeds and sized feature, the traditional heat transfer fluids, such as for example water, engine essential oil, ethylene glycol, etc. [14]., demonstrate the relative low warmth transfer performance. The very best potential alternative way of the heat transfer improvement is with the addition of solid additives in base fluid i.e. thermal conductivity of metallic or non-metallic solids may have two orders of magnitude greater than the conventional fluids. The enhancement of thermal conductivity of conventional fluids with the suspension of solid particles, such as for example micrometer-sized particles, has been popular for more than a century. The recent progress in components technology has managed to get possible to create nanometer-sized particles that may overcome these above complications. The innovative fluids suspended with nanometer-sized solid particles can transform the transportation and thermal properties of the base fluid, and make the fluid stable [1].

Thermal Conductivity values are essential every time usually to evaluate the heat transfer problem. Furthermore, thermal conductivity is normally a house of fundamental curiosity in developing the idea of fluids. The use of heat exchanger gadgets was increasing daily because of vast applications in commercial sectors. But conventional high temperature transfer fluids have got poor physical properties which worse the functionality of engineering apparatus. The thermal conductivity of typical high temperature transfers liquids such as water, propylene glycol, ethylene glycol or engine oil can be improved by the work of Ahuja [2], by adding micro/millimeter sized suspended particles in it. Adding suspended particles of micro/millimeter sized particles have some drawbacks such as sedimentation, fouling, erosion and improved pressure drop and it was considered not suitable for heat transfer medium. The heat transfer fluids suspended by nanometer sized particles called Nano fluids is developed to overcome the above drawbacks. Choi [3] at Argonne National Laboratory, USA showed that the thermal overall performance could be improved by adding nanoparticles in conventional fluids. Numerous investigations by Choi [3] have demonstrated that, actually for low concentrations of suspended nanoparticles in fluid exhibit high thermal conductivity.

The Al_2O_3 nanoparticles were selected to prepare the water-based Nano fluids in this scholarly study because of their chemical stability. Preparation of Nano fluids may be the key stage in the use of nanoparticles for steady Nano fluids. Two types of methods have already been employed in creating Nano fluids: the single-step technique and the two-step technique. The single-step technique is an activity combining the planning of nanoparticles with the formation of Nano fluids, that the nanoparticles are straight made by the physical vapor deposition technique or the liquid chemical substance technique (Choi, 1995, Eastman et al., 1997) [4]. The procedures of drying, storage, transport, and dispersion of nanoparticles could be avoided, therefore the aggregation of nanoparticles is certainly minimized and the balance of fluids is improved. But a drawback of the technique is that just low vapor pressure fluids are appropriate for the process. The applications are tied to it of the technique. The two-step way for preparing Nano fluids is certainly an activity by dispersing nanoparticles into base liquids. Eastman et al. (1997), Lee et al. (1999) , and Wang et al. (1999) [5] used this method to produce the Al_2O_3 Nano fluids. Nanoparticles used in the technique are produced seeing that a dry out powder by inert gas condensation firstly, chemical substance vapor deposition, mechanical alloying, or the other suitable methods prior to the Nano-sized powder is then simply dispersed into a fluid in the next processing stage. This step-by-step technique isolates the planning of the Nano fluids from the planning of nanoparticles. As a total result, aggregation of nanoparticles usually takes place in both steps, along the way of drying especially, storage, and transport of nanoparticles. The aggregation would not only lead to the clogging and settlement, but affect the thermal properties also. The methods such as for example ultrasonic agitation or the addition of surfactant in to the fluids can be used to reduce particle aggregation and improve dispersion behavior. Since Nano powder synthesis methods have been commercialized, there are potential financial advantages in using the two-step synthesis technique. But a significant problem that should be solved may be the stabilization of the suspension to prepare ourselves.

2. NOMENCLATURE

C_p	Specific heat capacity, J/kg K
d	Particle diameter, m
k	Thermal conductivity, W/mK
k_b	Boltzmann constant, J/K
n	Shape factor, dimensionless
T	Temperature, K
Greek Symbol	
β	Ratio of nanolayer thickness to particle radius, dimensionless
Ø	Volume concentration, %
μ	Absolute viscosity, Ns/m2
ρ	Density, kg/m3
ψ	Sphericity, dimensionless

Subscripts

bf	Base Fluid
cp	Centi Poise
eff	Effective
nf	Nanofluid
P	Particle
r	Relative

3. THEORETICAL INVESTIGATION

3.1 Thermal Conductivity

From the experimental results of many researchers, it was find that the thermal conductivity of nanofluids was changes by the base fluids of nanoparticles, the volume of concentration, shape of nanoparticles and the temperature. The Maxwell [6] was the first model to determining the thermal conductivity of liquid-solid suspensions. The effective thermal conductivity is given in equation (1):

$$k_{eff} = \frac{k_p + 2k_f + 2(k_p - k_f)\varphi}{k_p + 2k_f - (k_p - k_f)\varphi} k_f \qquad (1)$$

k_p, k_f, and Ø were the thermal conductivity of the particle and base fluid and the particle volume fraction in the suspension, respectively.

In advance to Maxwell equation, the Hamilton and Crosser model [7] was used for determining the effective thermal conductivity of a two-phase mixture. The model was given in equation (2):

$$k_{eff} = \frac{k_p + (n-1)k_f + (n-1)(k_p - k_f)\varphi}{k_p + (n-1)k_f - (k_p - k_f)\varphi} k_f \qquad (2)$$

where n is defined as n=3/ Ø and Ø was the sphericity. For the spherical shape particle, the sphericity (Ø) is 1.

In addition, Bruggeman [8] analyzed the interactions among randomly distributed particles by using the mean field approach. The Bruggeman model [9] was given in equations (3):

$$k_{eff} = \frac{1}{4}[(3\varphi - 1)k_p + (2 - 3\varphi)k_b] + \frac{k_b}{4}\sqrt{\Delta} \qquad (3)$$

where k_{eff} was the thermal conductivity of liquid with particle suspension, Ø was the volume fraction of particles and k_p & k_b were the thermal conductivities of the base fluid and the particles respectively.

Timofeeva et al. [10] has expressed a mathematical model. The expressed model can be written as in equation (4) & (5):

$$k_{nf} / k_{bf} = 1 + \frac{3(k_p - k_{bf})\varphi}{k_p + 2k_{bf}} \qquad (4)$$

$$x = \frac{k_p}{k_{bf}} \qquad \beta = \frac{k_p - k_{bf}}{k_p + 2k_{bf}} = \frac{x-1}{x+2} \tag{5}$$

The dependence of thermal conductivity to temperature and concentration were proposed by Vajjha and Das [11]. The empirical model was proposed in equation (6):

$$k_{nf} = A(\varphi) + B(\varphi)T + C(\varphi)T^2 \tag{6}$$

The coefficients A, B, C were polynomial functions of concentration. From all the above study, it can be seen that there are no general models to explain the strange behavior of the nanofluids including the viscosity and also the effective thermal conductivity. No reliable theory has predicted for the thermal conductivity of nanofluids. The significant differences between experimental data and theoretical models demonstrate the necessity of experimental workings.

4. PREPARATION OF NANOFLUIDS

During the experiment we dispersed the Al_2O_3 Nanoparticle with the average diameter of 25nm and particle density of 3.7 g/cm^3 into 100ml of the de-ionized water [16]. Oxide-particle volume concentrations are usually below 5% to be able to maintain moderate viscosity raises [12].

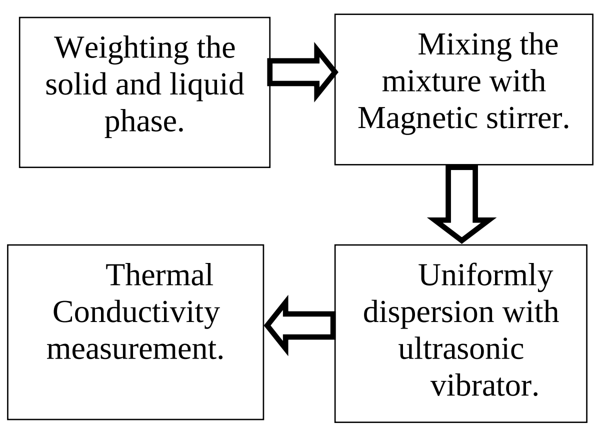

Fig. 1 Preparation of Nano fluids

5. THERMAL CONDUCTIVITY MEASUREMENT OF NANOFLUIDS

In our study, hot-wire method was used to gauge the thermal conductivity of Nano fluids. The accuracy of the equipment was found to be ± 0.1 of readings. For measurement of the thermal conductivity the vessel with tested sample was positioned within the temperature managed bath and sample temperature was checked by a thermocouple inserted into the vessel. All of the data were used 3 times and the common of 3 values was used for analysis [15]. Figure 2 shows the apparatus for measuring thermal conductivity of fluids in this apparatus Nichrome wire was used as a hot-wire with the diameter of 0.38mm. When a uniform voltage was supplied to the circuit, the electric resistance of the Nichrome wire rises with the temperature of the wire, and the voltage output was measured by an A/D converting system. Details of this method can be found in other literature [13]. The thermal conductivity was calculated, as in equation (7).

$$k = \frac{q}{4\pi(T_2 - T_1)}\ln(t) \tag{7}$$

Where,

k = Thermal conductivity of fluid

q = Heat supplied

T_1 = Initial temperature of fluids

T_2 = Final temperature of fluids

t = Time taken for the temperature rise

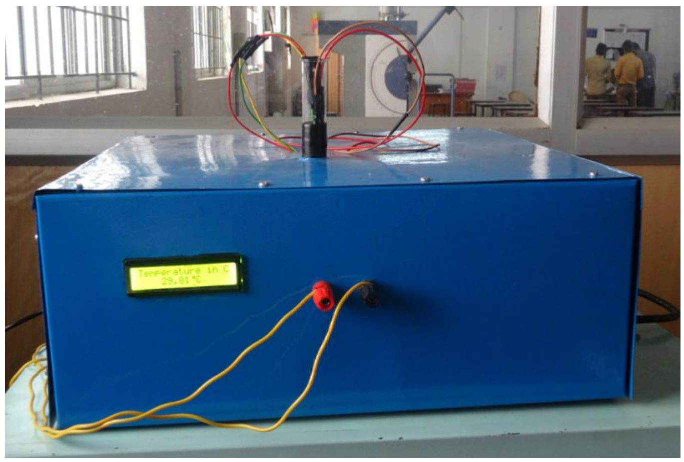

Fig. 2 Thermal conductivity measuring apparatus for fluids

6. RESULTS AND DISCUSSION

The graph shows the comparison of thermal conductivity of Al_2O_3 value to the standard thermal conductivity value at different temperatures. It is found that thermal conductivity of Nano fluid containing Al_2O_3 increases on comparing with the standard liquid. The increase in thermal conductivity ranges from 4-6% which can make some valuable change in heat transfer properties.

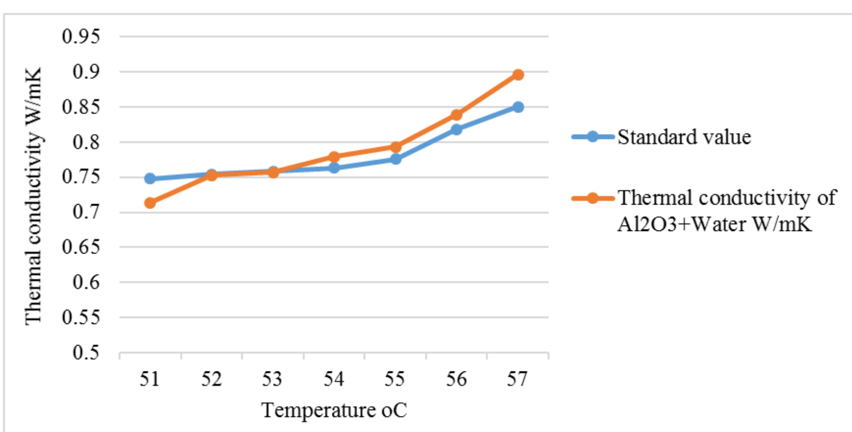

Fig.3 Temperature vs Thermal conductivity of Al_2O_3

7. CONCLUSION

The effect of temperature on the enhanced effective thermal conductivity of Nano fluids is important for theoretical understanding and needs to be considered for the model development. The thermal conductivity of the nanoparticle suspensions is dependent on the size of the nanoparticles, the interaction between the particle and liquid, and the thermal conductivity of the base fluid. In the current study, the Thermal conductivity of Nano fluids containing Al_2O_3 Nanoparticle is experimentally investigated. The experiments are made to find thermal conductivity by the suitable apparatus at various temperature ranging from 50-60^{o}C. The observations are tabulated and analyzed. It is to be found that Thermal conductivity rate of enhancement increases with in temperature. The thermal conductivity is found to be increased by 5% on adding Al_2O_3 Nanoparticle and the highest enhancement is found beyond 55°C.This can minimize some wear of the thermal equipment and hence increase some performance of thermal system.

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